Title: Cannonball!

Note: This activity was developed directly from "Activity 10: Projectile Motion" on page 39 in the book; *Exploring Physics and Math with the CBL System* by Chris Breueningsen and Wesley Krawiec, published by Texas Instruments)

Links to Outcomes:

- **Problem Solving** Students will explain how measurements can be used to obtain velocity. Students will use parametric equations to predict positions of a projectile.
- **Reasoning** Students will explain appropriateness of computations and models.
- **Connections** Students will use empirical data to generate mathematical models. Students will observe connections between experimental results and outcomes predicted from mathematical models.
- **Measurement** Students will make measurements of size and distance manually. Students will make measurements of time intervals via the Calculator Based Laboratory (CBL) / TI-82 system.
- **Technology** Students will use the CBL / TI-82 system.
- **Real-World Applications** Students will demonstrate an understanding of velocity via distance/ time measurements. This applies to any real-world situation involving velocity e.g., navigation, weapons systems, accident investigations, use of a "radar gun."
- **Application of Science** Students observe that all objects fall at the same rate.
- **Underpinnings of Calculus** Students' calculation of velocity over extremely small time intervals is a step towards the limit process which is central to the study of Calculus.
- **Cooperation** Students will work cooperatively to collect and analyze data and to report the findings in a written summary.
- **Communication** Students will demonstrate the ability to express orally observations of physical phenomena and explanations of the utility of mathematical models. Students will summarize all observations and results in formal written format in a group report.

Brief Overview:

This lesson is a group activity in which students compute the velocity and motion of a projectile. Some crude measurements of size and distance are made with a meter stick and calipers and some sophisticated measurements of very small time intervals are made with the CBL / TI-82 system. The students perform appropriate calculations to make discoveries regarding velocity, motion, and "free-fall."

Grade/Level:

Grades 8 - 12
With appropriate adjustment or extensions this lesson could be used with GT level classes as well as below grade-level classes.

Duration / Length:

One to three 90-minute periods, depending on the extensions one uses and the number of students in the class.

Prerequisite Knowledge:

Some familiarity with the TI-82
Familiarity with graphing
Ability to make manual measurements
Awareness that velocity = distance / time

Objectives:

Observe projectile motion
Measure range of projectile
Use CBL / TI-82 system to measure extremely small time intervals
Use CBL / TI-82 measurements to compute velocity of a projectile
Generate parametric equations of motion
Describe the motion of a projectile with parametric equations
Discover the relationship between: horizontal velocity, range and "falling time"
Work cooperatively in groups
Express observations / conclusions in writing

Materials:

CBL and TI-82 connected to a photogate, ramp with 3 positions marked, tape, white paper, carbon paper, student worksheets labelled: Lab Direction Sheet, CBL Instruction Sheet, Data Collection Sheet, Modelling/Analysis Sheet, a steel ball, a meter stick, a red marker, and calipers.

Development/Procedures:

Set up the CBL / TI-82 system as described on pg. 40 of *Exploring Physics and Math with the CBL System* by Chris Brueuningsen and Wesley Krawiec. You will find directions for operating the apparatus on the same page, more detailed directions for this activity are on our Lab Direction Sheet.

Students should be divided into groups of three. Each group will need approximately 10 minutes at the Lab Station to collect data. If there are not enough labs, then other students should be engaged in other activities while this goes on. Here are some suggestions for the "other activity":

- use the "Parabola Worksheet" included in our Extensions section; a series of CBL stations would be ideal; then all students could do the lab simultaneously (equipment limitations probably make this unrealistic)
- several CBL stations doing different activities could be set up with students moving from one to the other (this would be limited by availability of equipment and the amount of teacher direction needed at each station)
- finally, some appropriate "support" activity from the text could be assigned.

As each group finishes collecting data they return to their desks to discuss and analyze their data and respond to all questions on the Modelling / Analysis Sheet. The final summary is turned in the next day in Lab Report format (one report per group).

Evaluation:

Classroom observation and Lab Report.

Extensions:

Students can be given the equations $x = v_i(\cos A)t$ and $y = h + v_i(\sin A)t - 4.9t^2$ and asked to explain why the cosA is not in the "x" and the $v_i(\sin A)t$ is not in the "y" equation of our lab.

Students can be asked to do the "Target Activity" described below:

a. Three meter sticks will each have one soup or orange juice can taped at different heights. Students will note the height of the rim of the can, substitute this for y, and solve for t.

b. Students will then calculate a value for x and place the meter stick at a point x + (radius of the can) units away from the edge of the ramp.

c. Student will release the ball and it will go into the can.

Students can run the lab with different sized balls and compare resulting velocities, ranges, and falling times.

The entire lab can be run with #2 and #3 on the Modeling/Analysis Sheet withheld. Students would be asked to comment on the nature of the apparatus; explain the data being collected; and develop a method for using this data to calculate velocity.

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A. Go to the Lab Station. You will find: tape, white paper, carbon paper, data collection sheets, a ramp with 3 positions marked, a steel ball, a TI-82 and a CBL connected to a "photogate," a meter stick, a red marker, and calipers.

B. Use the meter stick to measure the height (in Meters) from the red dot on the floor to the "photogate." Call this "h" and enter it on your Data Collection Sheet.

C. Use the calipers to measure the diameter of the steel ball. Call this "d" and enter it on your Data Collection Sheet.

D. We are now ready to begin the lab. Each group member will perform a different task. We will do the experiment 5 times with each group member doing the same task. We will then change tasks and repeat the experiment from a different starting position for 5 more "runs." We will then change for a third trial so that each group member will have performed all tasks.

The tasks are as follows:

1. RELEASER: releases the ball from the designated position and records the data supplied by other group members on the Data Collection Sheet.
2. CBL'er: Operates the CBL and TI-82 and reports readings to RELEASER.
3. CATCHER: Catches the ball after it hits , measures the distance it traveled and reports this to the RELEASER.

E. We are now in Trial #1. All data will be entered under "trial #1" on your Data Collection Sheet and all group members will perform the same task until "trial #2" starts.

Be sure each group member understands his/her task before proceeding!

1. The first thing to do is a trial run:
   The RELEASER puts the ball on the ramp at position #1
   The CATCHER gets ready
   Release the ball
   The CATCHER notes where the ball hits
   The CATCHER tapes a piece of white paper to this spot and tapes a sheet of carbon paper (carbon side down) to the white paper

   Now we're ready to begin!

2. The CBL'er controls the pace of the experiment. He/she follows all instructions on the CBL Instruction Sheet (read these instructions now).

   When the CBL'er says "release", the RELEASER releases the ball from position #1.
   The CATCHER stops the ball after it hits the carbon paper.
   The CBL'er reads the time on the TI-82 aloud and the RELEASER records this time on the Data Collection Sheet under "trial #1."

   Do this 4 more times (giving a total of 5 runs) with each person performing the same task.

3. Now the CATCHER removes the carbon paper. There are a cluster of points on the white paper from where the ball hit. Use the red marker to mark what you believe to be the center of this cluster with a red star.

4. The CATCHER uses the meter stick to measure the distance (in Meters) from the red dot on the floor to the red star. This distance is reported to the RELEASER who enters it as R on the Data Collection Sheet.

5. Pick up the white paper.

6. We are now ready to begin the next trial (#2, then #3). Each group member now has a new task. Decide what these are before proceeding. Use position 2 then 3 on the ramp instead of position 1.

   Finally, you will repeat these same steps for a third trial so that every position on the ramp has been used and the appropriate entries in Trial #1, Trial #2 and Trial #3 on your Data Collection Sheet have been filled in and every group member has had a turn at every task.

   Now return to step #1 for trial #2

7. When trials #2 and 3 have been completed leave the Lab Station and proceed to the Modelling Station.

CBL LAB **CBL Instruction Sheet**
Title: Cannonball

Group:_____

Group Members:

1. Turn on the CBL and the TI-82. Start the PHOTOGATE program on the TI-82. Select STATUS CHECK from the Photogate menu. Press {ENTER} to check the Photogate system for alignment. The TI-82 should display "UNBLOCKED" on the screen. If it does not display "UNBLOCKED" then notify the teacher. Do not adjust the equipment.

2. To end the STATUS CHECK press {ON}. Press {2} to quit. Re-start the PHOTOGATE program on the TI-82 by pressing {PRGM}. Press {ENTER} to run the program. Select GATE MODE by pressing {ENTER}. Press {ENTER} to arm Photogate and immediately tell RELEASER to release the ball (this will result in data being collected).

CBL LAB **Data Collection Sheet**
Title: Cannonball

Group: _____

Group Members:

h = _____ d = _____

Trial # 1

T1	
T2	
T3	
T4	
T5	
Tavg	

Trial # 2

T1	
T2	
T3	
T4	
T5	
Tavg	

Trial # 3

T1	
T2	
T3	
T4	
T5	
Tavg	

R1 = ____ R2 = ____ R3 = _____

v1 = ____ v2 = ____ v3 = _____

CBL LAB **Modelling/Analysis Sheet**
Title: Cannonball **Page 1**

Group: _____

Group Members:

1. For each trial take the average of the 5 times that were collected and record that average under Tavg on your Data Collection Sheet.

2. Calculate the velocity of the ball by dividing the diameter of the ball by Tavg. Record the velocities from the 3 trials on the Data Collection Sheet under: v1, v2, v3.

3. Explain how the calculation in #2 gives velocity. (Respond on a separate sheet)

4. The ball's path can be described by the parametric equations below:

$$x = vi * t$$

$$y = h - 4.9 * t^2$$

where: vi = initial velocity of the ball
h = initial height of the ball
t = time in seconds

5. On your Data Collection Sheet you have a value for h and values for vi for each trial. Substitute these into the equations above and write the resulting equations below, giving you equations describing the motion of the ball for each trial !

Trial # 1	Trial # 2	Trial # 3
_____	_____	_____
_____	_____	_____

6. Explain how x and y relate to the motion of the ball. (Respond on a separate sheet.)

7. Enter the equations from each trial in the TI-82 in parametric mode. Adjust the viewing window so that you have an appropriate graph of the ball's motion. (Sketch this graph on a sheet of graph paper.)

8. Use the {TRACE} function to find the point where the TI predicts the ball hits for each trial. Enter this below.

R1 = _____ R2 = _____ R3 = _____

9. How long did it take for the ball to travel from the end of the ramp to the floor?

   T = _____

10. Use the TI-GRAPH LINK to obtain a printout of the ball's path for each trial. Label the coordinates of the ball's point on the printout.

11. For each trial compare the range obtained from the TI-82 with the experimentally determined range. Calculate a percent "error" for each trial.

$$\% \text{ error} = \frac{\left| \text{experimental range} - \text{calculated range} \right|}{\text{calculated range}}$$

Trial # 1	Trial # 2	Trial # 3
% error = _____	% error = _____	% error = _____

12. Discuss why there could be "error" in this experiment. (Respond on a separate sheet.)

13. How do the "falling times" compare for different trials? Explain this result. (Respond on a separate sheet.)

14. Now, summarize your observations and conclusions. State what you've learned. Put all of this on a separate sheet. This is your Summary Sheet. For your grade for this Lab you turn in 3 things:

    1. Data Collection Sheet
    2. Modelling/Analysis Sheet (and all related sheets)
    3. Summary Sheet